



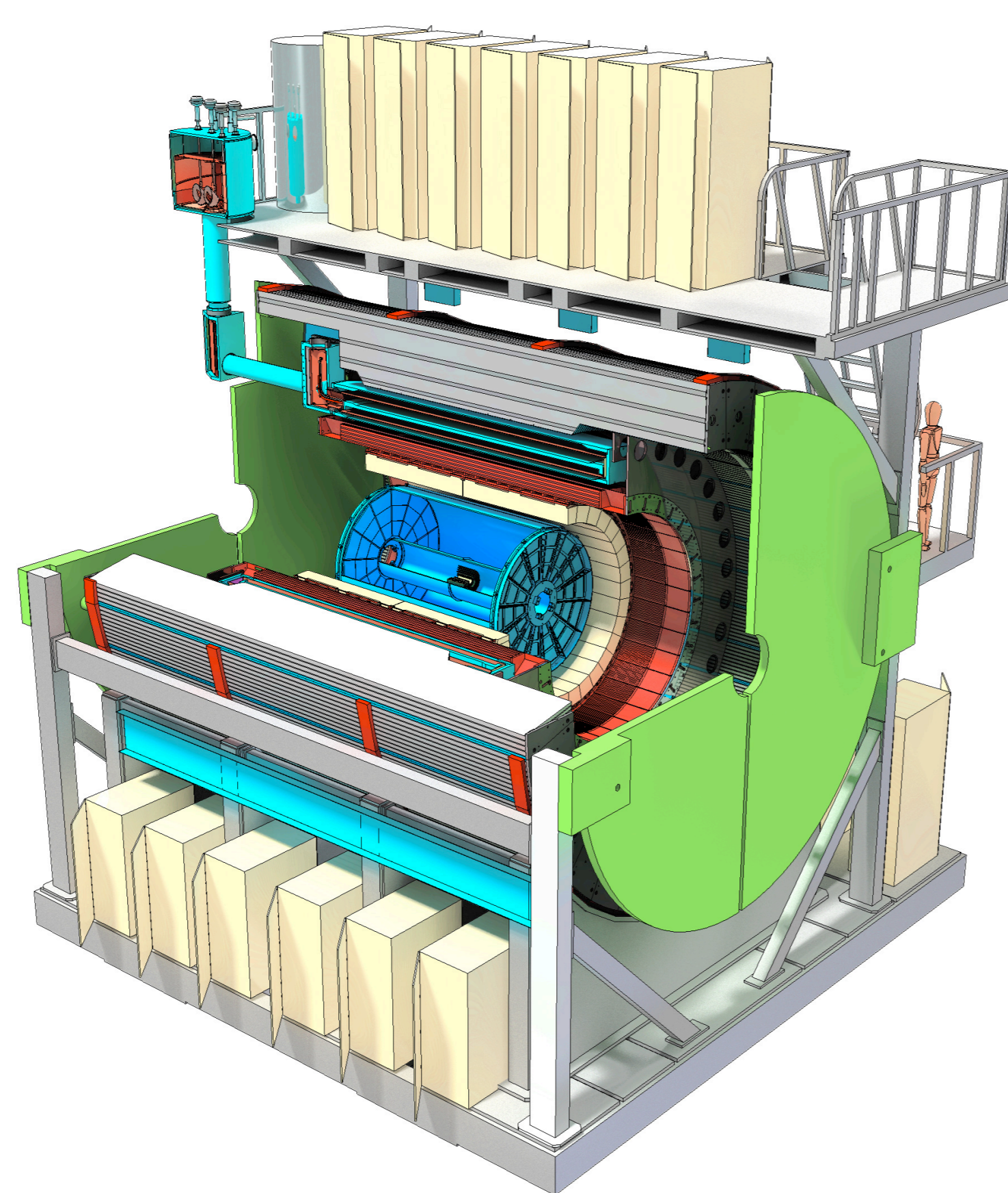
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## Abstract

sPHENIX is the next generation detector at the Relativistic Heavy Ion Collider (RHIC) designed to explore the properties of the Quark-Gluon Plasma through measurements of jet properties. The detector consists of a 1.5T superconducting solenoid, tracking, electromagnetic and hadronic with a high speed data acquisition system. The calorimeters use a common readout designed based on silicon photo-multipliers (SiPMs) as the optical sensors with a continuous digitization of the analog signals. We will present the design requirements and technology choices, along with preliminary performance results from prototype testing at the Fermilab Test Beam Facility as part of experiment T-1044.

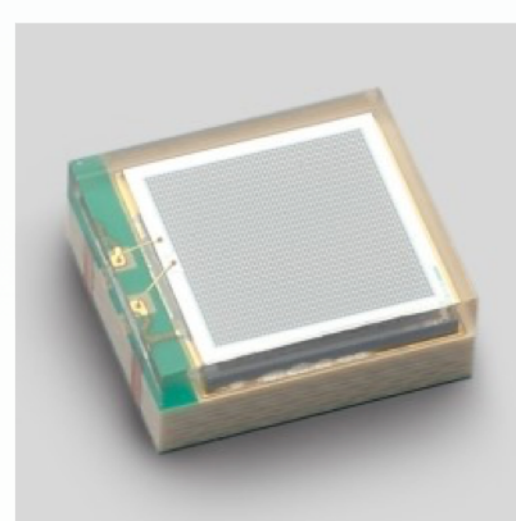
## The sPHENIX Detector.

- Uniform acceptance  $-1.1 < \eta < 1.1$  and  $0 < \phi < 2\pi$
- T Solenoid (Former BaBar Solenoid)
- Tracking- Essential for Heavy Flavour Physics Program
  - MAPS Vertex Detector
  - Silicon Strip Intermediate Tracker
  - TPC for momentum determination
- Calorimetry- Essential for Jet Physics Program
  - Electromagnetic (EMCal): Tungsten-Scintillating Fiber (W/ SciFi)
  - Inner Hadronic Calorimeter (iHCal): Stainless Steel Plates and scintillating tiles with waveshifting fibers .
  - Outer Hadronic Calorimeter (oHCal): Steel plates and scintillating tiles with waveshifting fibers. Serves as flux return
  - 24576 EMCal towers and 3072 HCal towers
  - High DAQ rate, 15kHz



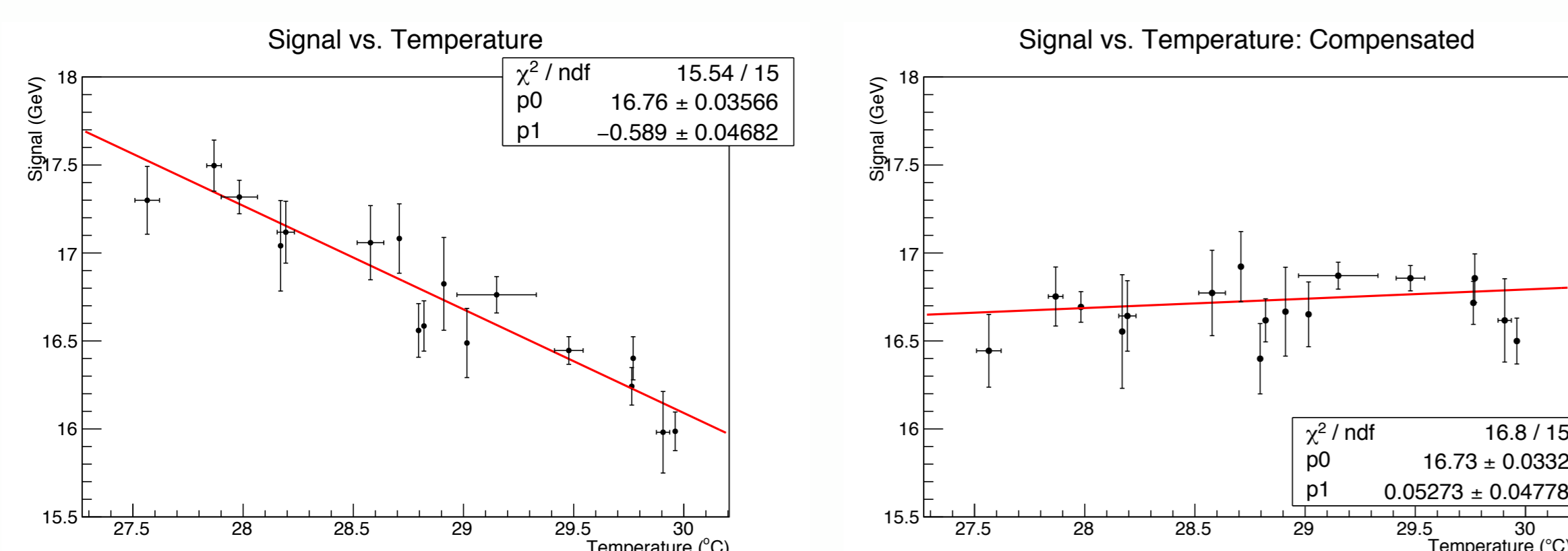
## Optical Sensors

The Hamamatsu S12572-22-015P has been chosen as the optical sensor. Device features:



- Immune to magnetic fields
- Compact:  $3 \times 3 \text{ mm}^2$
- 44K  $\mu\text{-cells}$  (pixels)
- $10^5$  Gain
- 4 SiPMs per EMCal tower
- 4/5 SiPMs per HCal tower (one per tile)
- Gain sensitive to temperature variations
- Neutron irradiation increases leakage current

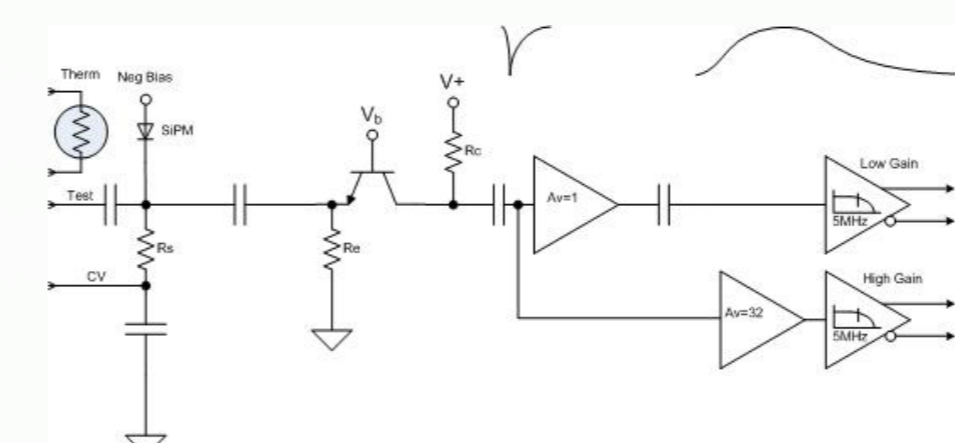
The gain varies linearly as a function of temperature and by monitoring the temperature of the SiPM one can correct for the changes in the gain due to temperature fluctuations. The figures below show the data for the EMCal before and after applying a correction for the gain based on the monitored temperature of the SiPM.



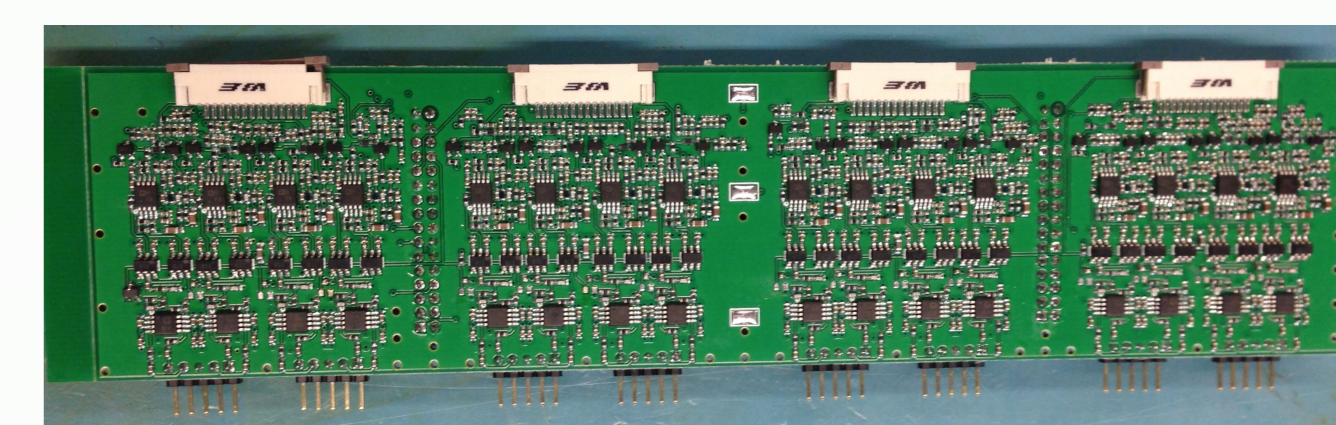
The average calibrated signal (in GeV) as a function of temperature for a  $5 \times 5$  tower region of the EMCal taken during the 2016 T-1044 test beam run at the Fermilab Test Beam Facility. The figure on the left shows the average tower energy with out a temperature correction, which shows a variation of  $-3.68 \pm 0.29 \text{ \%}/^\circ\text{C}$ . On the right is the average tower signal after a temperature correction is applied, which is consistent with temperature dependence within the statistical uncertainty.

## Analog Front End

The EMCal and HCal use a similar front end analog design differing in gain and packaging to account for differences in the detector designs. Signals from the 4/5 SiPMs associated with an EMCal/HCal tower are passively summed before amplification. The amplifier front end is a common-base configuration acting like a transresistance amplifier presenting a low impedance to the SiPMs. A charge injection circuit provides a fixed test pulse to the amplifier for testing purposes. The gain stage has both a normal gain (x1) and high gain (x16 for EMCal and Inner HCal, x32 for Outer HCal) amplification. A shaping circuit follows and provides a 30 nsec peaking time suitable for 60 MHz sampling. The analog signals are then driven differentially to the digitizer modules located nearby. For the test beam run, the EMCal gain output was selectable through the slow control system, while for the HCal both gain ranges were recorded during normal data taking.



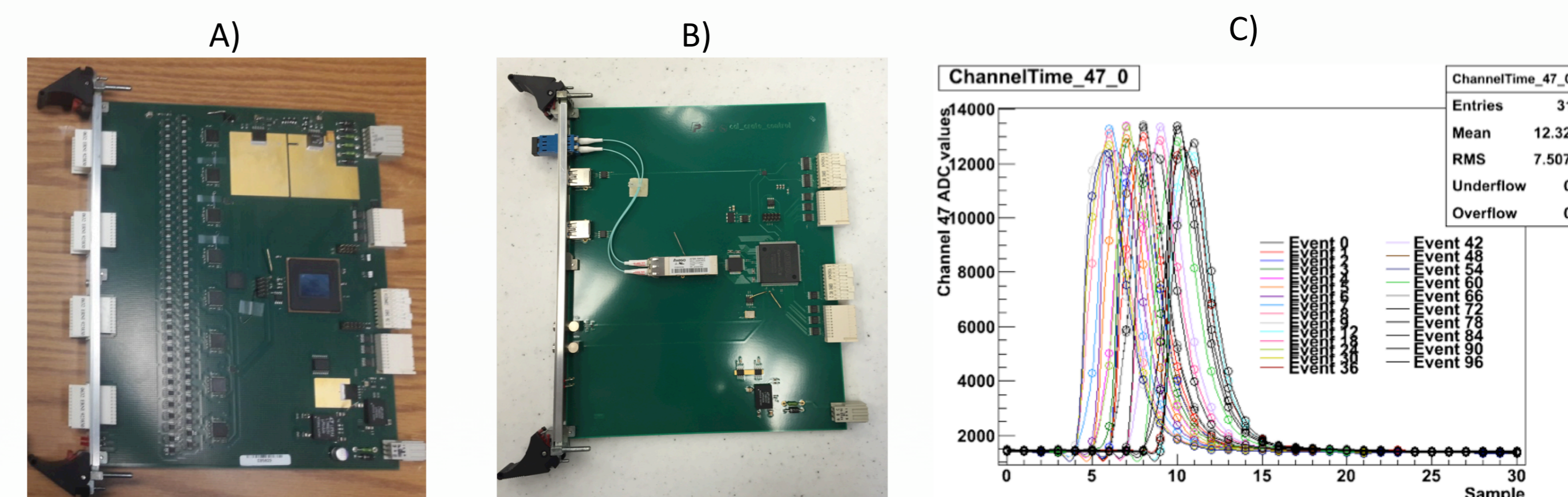
Schematic of the Outer HCal preamp circuit used in the T-1044 test run at FTBF



Picture of the EMCal preamp modules. The EMCal module services 16 (2x8) Towers, while the HCal preamp (not shown) is for a single tower

## Digital Back End

The differential analog signals from the EMCal and HCal are received by the next generation sPHENIX Digitizer System. The system consists of digitizer modules, XMIT modules and crate controllers. Each digitizer module consists of 64 channels of 14 Bit ADCs running at 6 times the beam crossing frequency (60 MHz typical, 65 MHz max). Upon receipt of an experimental trigger, up to 31 time samples (programmable) per channel are transmitted to the XMIT module, where they are formatted into a standard sPHENIX data packet before being transmitted to the sPHENIX data acquisition system via optical fiber. In addition, the digitizer module is capable of producing trigger primitives (cluster energies, number of clusters,...) and transmitting them directly via optical fiber to the sPHENIX trigger system for trigger processing. The system has been designed with prototype modules now in the testing stage.



Pictures from left to right: A) 64 Channel ADC module, analog signals come into the board on the right. B) ADC Crate controller, which provide configuration information for the digitizer and XMIT modules. C) Signals from an pulsed LED illuminating an SiPM and readout using an HCal preamp high gain channel. In this plot, 10 events are superimposed on the plot. The time jitter is a result of the LED pulse not being synchronized with the ADC clock. Readout was through the full ADC-XMIT-DAQ chain.

## Conclusions

- Silicon Photo-Multipliers have been selected as the preferred optical sensor for the Electromagnetic and Hadronic calorimeters.
- A common analog front end for the calorimeter readout has been designed, prototyped and tested in an experimental environment using the Fermilab Test Beam Facility (FTBF). Preliminary results show that the analog electronics meet the design requirements of the sPHENIX detector readout.
- A common digitizer system capable of operating at 60 MHz has been designed and prototyped. Testing is ongoing to verify that the system meets the design requirements for the sPHENIX calorimeters.
- A full chain test of the analog front end and digitizers is expected to be done in 2018.
- sPHENIX will be installed starting in 2021 with first data in 2022